DESIGN OF AN AUTOMATIC CAISSON EXCAVATOR

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ARMOUR INSTITUTE OF TECHNOLOGY

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Alfred D. Phillips
Prof. Civil Engineering

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A DESIGN

OF AN AUTOMATIC CAISSON EXCAVATOR

A THESIS

Presented by

Victor E. Cole

To the

PRESIDENT and FACULTY

FOR THE DEGREE OF

Bachelor of Science in Civil Engineering.

Having completed the prescribed course of

Studies of

CIVIL ENGINEERING.

Alfred E Phillips
Prof Civil Engineering

H. M. Raymond
Dean. Eng Studies

L. C. Monin
Dean of Cult. Studies.

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PREFACE

The march of civilization has always been towards the substitution of machinery for manual labor.

Caissons and their automatic excavation deals with something more than the mere substitution of machinery for the "sand hog", since it reduces to a minimum the number of people that are required to endanger their lives through Caisson disease.

Hence there are two considerations, the economics and the betterment of humanity---these are the leading forces in our present day civilization.

Acknowledgement of indebtedness and thanks is hereby made of the great assistance received from Mrs. Julia A. Beveridge, Librarian of Armour Institue of Technology and Mr. Stanley Dean, Instructor in the Civil Engineering Department of Armour Insttute of Technology.

Victor E. Cole.

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INTRODUCTION

Roads are the offspring of civilization, they are the physical symbol by which to measure the progress of any age or people. As has been said, since time immemorial that a chain is no stronger than its weakest link, hence a road is perfected only when it passes over all obstacles. The greatest of these, are large rivers and the degree of success that is attained in spanning these, measures the height of civilization.

The hardest problems in Civil Engineering deal with the design and erection of long span bridges. The sub-structure of these are of many types with the ultimate view in all for rigidity. This is attained in the highest degree only when the supports rest on bed rock.

The means by which bed rock is reached is the pneumatic caisson. This has been operated only by manual labor. With the idea in mind of cutting down this expense and also in saving many from coming in contact with the dreaded caisson disease, a general design has been laid out to dig caissons automatically.

GENERAL PROBLEM

Caissons are used in all places where it is advisable to rest the sub-structure of any form of building on the bed rock. This is best obtained by building the sub-structure as it is being sunk to the bed rock , the building being necessarily about the same rate as the excavation below. The problem consists of digging the earth and the raising of this earth to the surface. The digging is performed by a bucket excavator of the same type as a ditch digger and the earth is raised to the surface by a bucket hoist.

The earth is dug in the chamber by the excavator, dumped into the screw conveyer carried on top of the girder carriage, and from this conveyor it is dumped into the conveyor "H" running along the wall of the chamber. This last conveyor carries the earth to the bucket hoist opening. This opening is fitted with a continually revolving trap, which works on the same principle as the revolving winter entrance doors in the buildings. The earth once into the bucket hoist shaft, is quickly carried to the surface.

In this design there are four chambers each fitted with an excavator, which by itself controls three motions.

1: The revolving buckets.

2: The conveyor carried on the girder carriage.

3: The motion back and forth of the frame on the girder carriage.

The motive power is electricity, the contact with the motor being made by an insulated line along the web plate of the girder carriage.

1: The buckets are chain connected to the motor, and as long as this motor operates, the action of all three motions are continuous.

2: The operation of the conveyor is maintained by gear "C" connected to the main cog wheel "A". This gearing slides on a slotted shaft "B" which is geared to the conveyor shaft at both ends.

3: The motion on the girder carriage of the frame is reversed from side to side, each reverse sending the frame along the girder carriage in the opposite direction. This reversing is maintained

by two systems of pinions.

The drawing shows the frame moving to the left with the pinion "E" in action. As soon as the reversing catch engages the belt"D", this is thrown over and pinion"F"carries the frame to the right,where the reversing catch on this side throws the belt over again and the frame starts back to the left.

The raising of the girder carriage, its motion back and forth in the working chamber and the continuous action of the conveyors "H" are all controlled by gears and chain connections to the three motors "G".

THE DESIGN

The walls of the chamber are the most critical, as far as safety to the under-ground workers is concerned. This is not due to the vertical pressure of the caisson, as this is mostly counter-balanced by skin friction, but it is due to the earth pressure on the outside. Now it has been found that the air pressure is always in excess of the hydrostatic pressure, the difference ranging from two to five lbs. If the air pressure fell below the hydrostatic pressure, the working chamber would fill with water.

If we consider a drop in the air pressure to be two lbs. below the hydrostatic pressure, this will be an added load that the walls will have to carry before the outside and the inside pressure equalize. The lowest strata of sand is shown by the borings to be sixty-three feet below the surface. The sand pressure was found to be twenty lbs. per sq. ft. The pressure on the cutting edge itself=63 X 20 X 1= 1260 lbs.

The pressure on top of walls is (63-11)20 is 1040 lbs.

The added load due to the 2 lbs. per sq. in. is 288 lbs.

1: Calculation of thickness of outside plate.

The flange of 12" 31 1/2 lbs. I beam is 5", spaced 2 ft. center to center, the clear distance edge to edge of the flanges is 19".

The maximum pressure is 1260 lbs. plus 288 lbs. is 1548 lbs. The moment is 1550 X 2.5 is 3880 lbs.,inches. d^2 is 3880 X 6 ÷ 12 X 12000. d is .401". A 7/16" plate has a thickness of .4375" and this will be used.

2: Calculation of walls.

The maximum pressure on the cutting edge is 1040 lbs. plus 288# is 1328#. The moment of this about the upper part of the working chamber is 1328 X 121 X 6 is 964000# inches.

The moment due to the excess of 220# is 106000# inches. The total moment is 964000#" plus 106000#"is 1070000# in. This is the bending moment per lin. foot and for beams spaced 24"center to center, the necessary section modulus is 189.2 inches^3.

Moment of Inertia of a 12" I 31.5# is 215.8
" " " " one 7/16" outside plate is 406
" " " " Inside plate(4' deep) is 598
Summation AR^2 is 1230inches^4

The section modulus is 1230 ÷ 6.53 is 188.3 inches^3

These will be used.

3: Calculation of compression girder.

Moment is 16720 X $(21)^2$ X 12 ÷ 10 is 8,870,000# inches

The area of the flange is 8,870,000 ÷ 16 X 42 X 10^3 13.2 sq. in. Shear is 175000#. Thickness of web plate is 175000 ÷ 42 X 15000 is .278. Use 5/16" web plate. For flanges use two 6"X6" X 5/8" ∠s.

4: Calculation of column"C"

According to the Hand Book of the Cambria Steel Co., with a load of 175,000 # and the length of 20 ft. the necessary column is four angles 4 X 3 X 5/8 and 5/8 X 12 web plate.

5: Calculation of Tension Girder.

The walls of the working chamber having been cantilevered out from the body of the caisson, the con-

pression system was put in to relieve the high stress on the face of the concrete. A tension system will be put in to hold the top part of the I beams from being pulled out. The outward pull at the top of each I beam is 1150 X 11 X 11 ÷ 7 - 970 X 7 is 13290#. The moment on six lineal feet is 13,290 X 36 X 12. is 472500# inches. Section modulus for this 472500 ÷ 12,000 is 39.4. A 15" 33# channel will be used and 2 1/2" round clevise tie rods will be used to tie the tension system into the concrete.

6: Calculation of compression system around the air lock.

These girders have to take a column action of 350,000# and a bending action of the same.

Four angles 8 X 8 X 5/8 have an area of 38.44
One web plate 36 X 5/8 " " " " 22.5
The total area is 60.94

The bending moment due to the load is 8400000# inches.

Necessary flange area for this is 8400000 ÷ 15000 X 36 is 15.5 sq. in.

The area for shear is 14 sq. in.

The necessary flange area is 31 sq. in.

The total area is 45 sq. in., for the bending action.

The radius of gyration of this girder is 2 1/2".

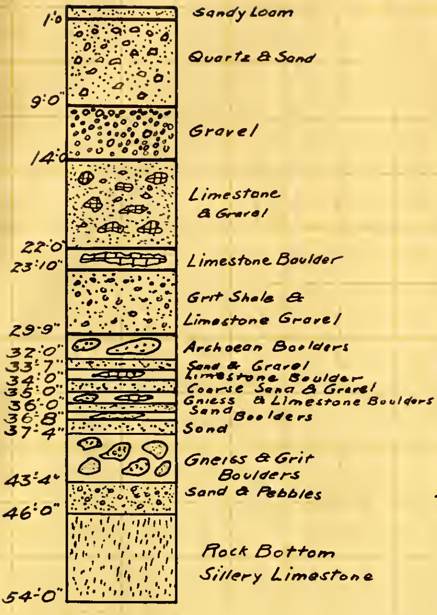
P equals $16000 - 70\frac{L}{R}$ is 12000 #. 175 ÷ 12 is 14.6.

The excess of the area used over that necessary for the bending action is equal to 60.94 - 45.00 which is 15.94. The necessary steel for the column action is 14.6 sq. inches. Since the area required is less than the area used, the girder is safe both as to bending and as to the column action.

The plate on the inside of the working chamber will be 1/4" throughout. This will also be heavy enough for the walls of the escape shafts and of the main entrance shaft.

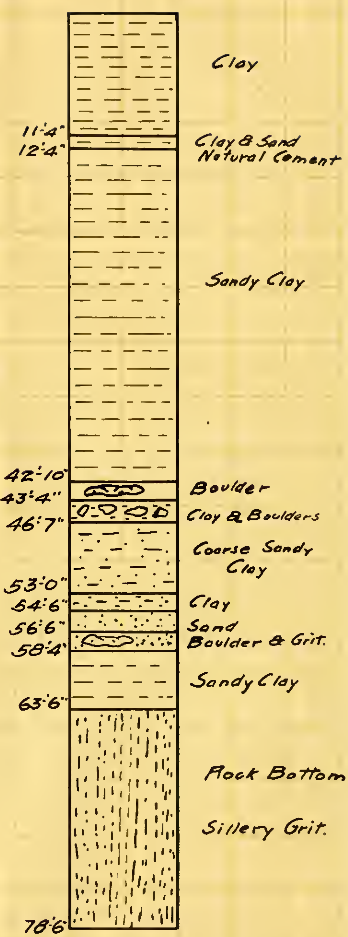
Temperature reinforcement:

General practice allows .2 of 1% of the area of the concrete for temperature expansion. This will be well taken care of by using 3/4" square rods spaced 2 ft. center to center both ways.



Bore Hole on North Side

50' East of ℄ of Bridge.

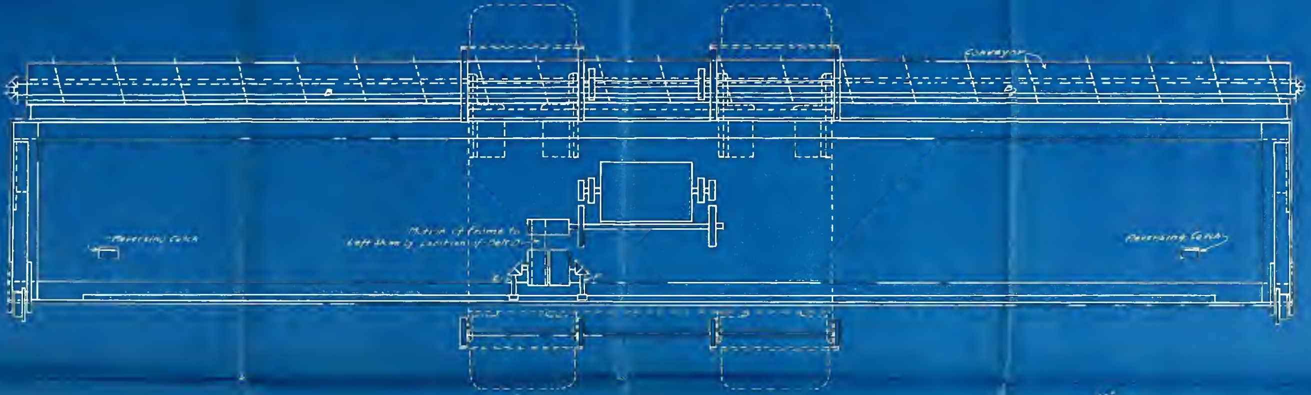


Bore Hole on South Side

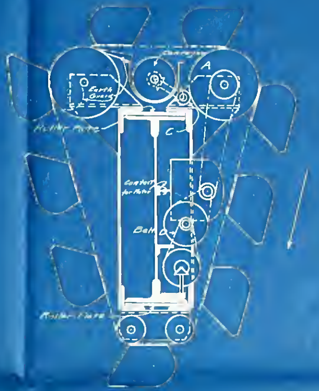
Close to South Cliff South Anchorpier
200 feet from foot of Cliff.

Drillings on North & South Sides of the St. Lawrence River
at the Site of the Quebec Bridge.

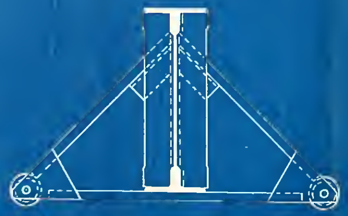
Victoria Cove -
Eight Miles above Quebec City - Quebec.



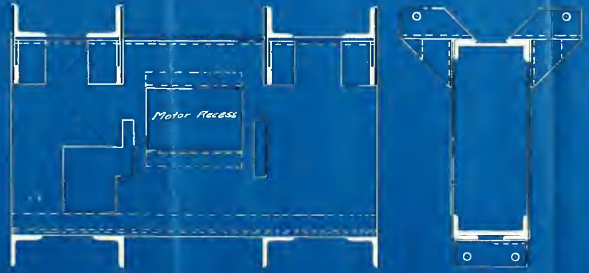
FRONT ELEVATION OF MECHANISM & GIRDER CARRIAGE
Scale 1"=1'0"



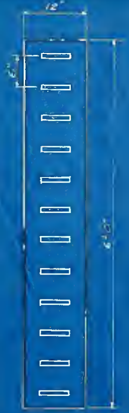
END ELEVATION
Scale 1"=1'0"



CARRIAGE CONNECTIONS FOR TRACK
Scale 1"=1'0"



FRONT & END ELEVATIONS OF
MECHANISM FRAME



ROLLER PLATE & BEARINGS - 6 in.

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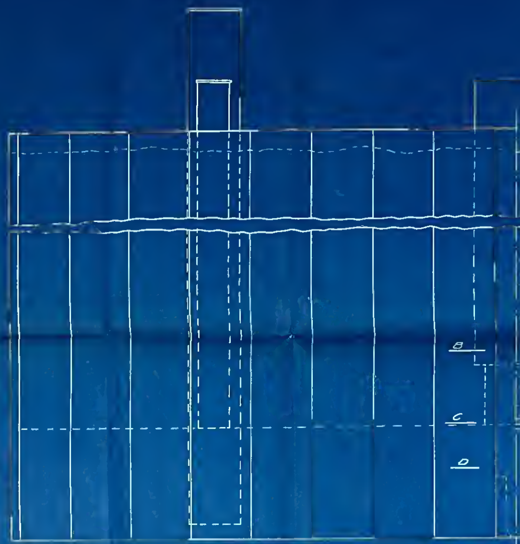
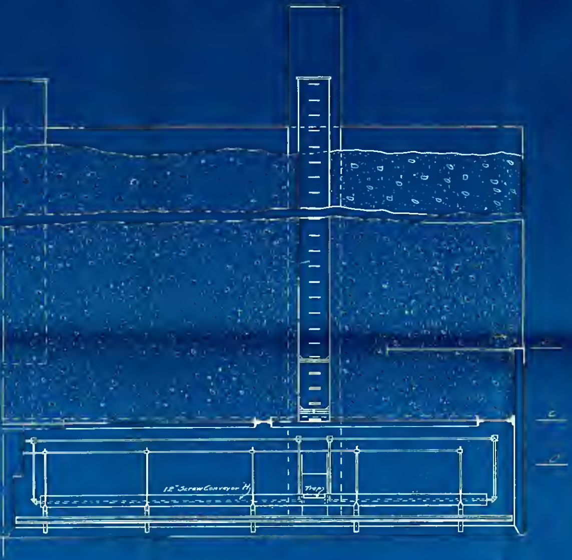
CIVIL ENGINEERING DEPARTMENT
DESIGN OF AN
EXCAVATOR FOR CAISSONS
SCALE 1"=1'0" MAY-19-1910.

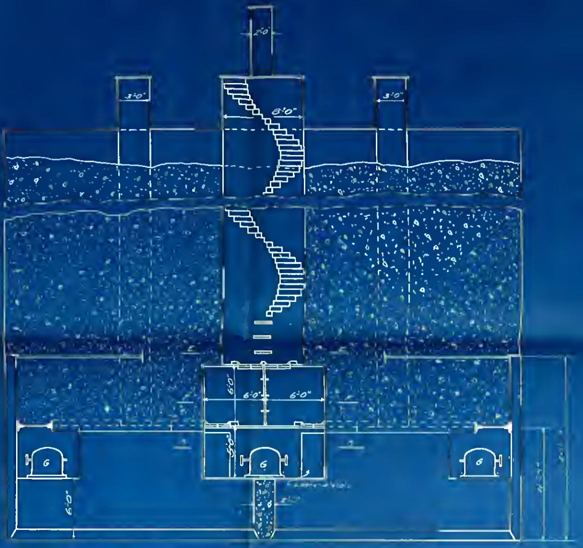
THESIS OF
L. E. Cole



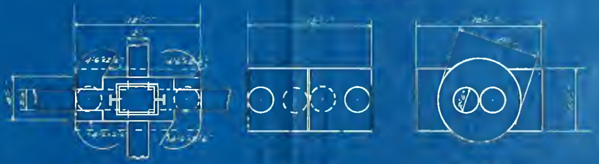
ELEVATION
Scale-1/8"=1'-0"



SECTION A-A
Scale 1/8"=1'-0"

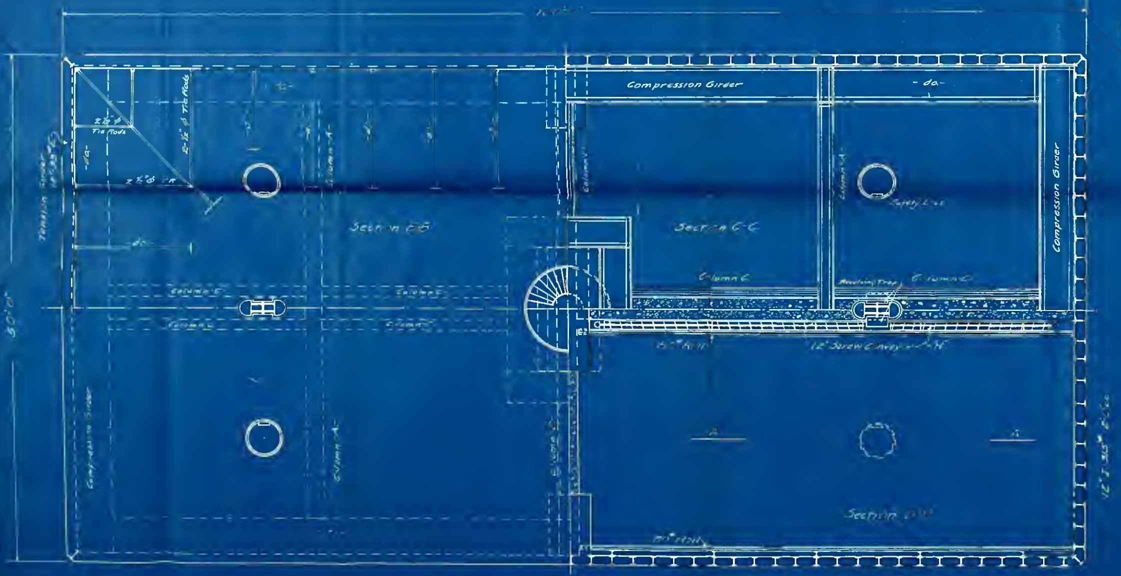


SECTION THRU MAIN SHAFT & LOCK
Scale 1/8"=1'-0"

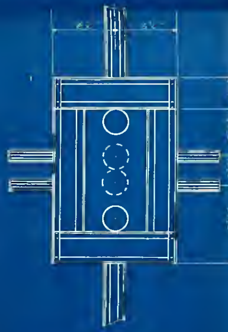


SECTION G-G
SECTION F-F
SECTION E-E

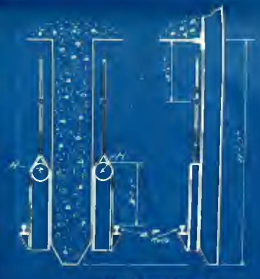
MAIN SHAFT OPENINGS — ALL LOCK DOORS 2'-6" DIA
Scale 1/8"=1'-0"



PLAN
Scale 1/8"=1'-0"



FRAMING FOR AIR LOCK
Scale 1/4"=1'-0"



RAIL CONNECTIONS
Scale 3/4"=1'-0"

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DESIGN OF A
CONCRETE-STEEL CAISSON
FOR AUTOMATIC EXCAVATION
SCALE 1/8"=1'-0"   MAY-19-1910.

THESIS OF   E. Cole